

Advanced Gasification-Based Fuel Conversion and Electric Energy Production System

Quarterly Technical Progress Report – Phase I

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ABSTRACT

The objective of this project is the development and commercial demonstration of an advanced biomass gasification-based power generation system at Boise Cascade Corporation's pulp and paper mill in DeRidder, Louisiana. The advanced power generation system is intended to meet the immediate needs of the forest products industry for highly efficient and environmentally friendly electricity and steam generation systems utilizing existing wood waste as the primary fuel resource. The novel system is based on three advanced technology components: GTI's RENUGAS[®] and 3-stage solid fuels combustion technologies coupled with one of the power generation approaches used in DOE's HIPPS program.

The project will be conducted by the Gas Technology Institute (GTI) and Boise Paper Solutions (Boise), the paper making division of Boise Cascade. The project team includes Babcock Borsig Power (BBP), Solar Turbines Inc., Carbona Corporation, the University of North Dakota Energy and Environmental Research Center (EERC), and Nexant LLC, a Bechtel technology and consulting company.

Phase 1 of the project is a technical and economic evaluation of the system at the DeRidder site. A Continuation Application will be submitted at the conclusion of Phase 1 for authorization to proceed to testing and design in Phase 2. Phase 2 includes pilot-scale verification of selected system components and preparation of a detailed engineering design and cost estimate for retrofit of the advanced power system at the DeRidder mill. Phase 3 will complete procurement and construction of the system at the DeRidder site along with all required permitting activities. Phase 4 of the project will include plant commissioning, startup and demonstration operations.

The primary project activity during the quarter was refinement of the power system configuration for the DeRidder mill. The modified configuration was reviewed with DeRidder mill management and Boise corporate personnel and with DOE and AF&PA Agenda 2020 representatives. A list of commercially available materials for the high-pressure, high-temperature air heater tubes was selected. Preparations were begun for the materials testing experiments to be conducted with samples of the selected materials exposed in DeRidder's PB No. 2. Two gas turbine configurations for the power system have been selected for further study. Heat and material balance calculations were started for the gasification section. In addition, DOE concurrence was received for the Budget Period 1 Project Evaluation Plan. Service Orders placed with Babcock Borsig Power (BBP) and Solar Turbines, Inc. were replaced as subcontracts. A subcontract was placed with Carbona Corporation for the Gasification Island Design Study.

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INTRODUCTION

Boise Cascade Corporation and the Gas Technology Institute (GTI) are cooperating to develop, demonstrate and place in continuous operation an advanced biomass gasification-based power generation system suitable for near-term commercial deployment in the Forest Products Industry. The system will be used in conjunction with, rather than in place of, existing wood waste fired boilers and flue gas cleanup systems. The novel system will include three advanced technological components based on GTI's RENUGAS[®] and three-stage stoker combustion technologies, and a gas turbine-based power generation concept developed in DOE's High Performance Power System (HIPPS) program. The system has, as its objective, to avoid the major hurdles of high-pressure gasification, i.e., high-pressure fuel feeding and ash removal, and hot gas cleaning that are typical for conventional IGCC power generation. It aims to also minimize capital intensity and technology risks. The system is intended to meet the immediate needs of the forest products industry for highly efficient and environmentally friendly electricity and steam generation systems utilizing existing wood waste as fuel resources.

EXECUTIVE SUMMARY

Project Objective: The overall objective of this project is to demonstrate the commercial applicability of an advanced biomass gasification-based power generation system at Boise Paper Solutions' pulp and paper mill located at DeRidder, Louisiana.

Background: The project team, led by GTI, will develop, design, install, demonstrate and place in continuous commercial operation and advanced biomass gasification-based power generation system including gasification, syngas reburning and indirect high temperature air heating technology and utilizing existing wood waste resources as fuel. The system will be integrated with existing powerhouse equipment, including the wood waste-fired stoker boiler and flue gas cleaning system, in a stepwise manner to insure the reliability of steam and power generation. Staged implementation will reduce technology risk, improve operator acceptance and allow energy, environmental and economic benefits to begin to be realized by the mill early in the project.

The project will be conducted in four phases over a period of 6 years. The phases are structured to provide a logical path to verify the technical and economic feasibility of the proposed biomass gasification-based power generation approach in Phase 1, with a Continuation Decision point prior to proceeding with pilot testing and detailed design. A detailed engineering design and cost estimate will be developed in Phase 2 with another Continuation Decision point prior to proceeding to Phase 3. Construction and demonstration of the system will be completed in Phases 3 and 4.

Boise's DeRidder mill has agreed to be the host site for the project, completing a major milestone ahead of schedule and allowing the design to center on the specific requirements of the host site early in the project. The major subcontractors for the project have been identified and approved by both DeRidder and DOE.

Status (June 30, 2002): The power system configuration was refined during the quarter to better meet the specific energy requirements and constraints existing at the DeRidder mill. The reconfiguration addresses several limitations in the application of the original system concept to DeRidder's Power Boiler No.2, including space and heat limitations for the air heater heat exchange surfaces inside the boiler, the desire by DeRidder to maintain the maximum steam production possible from the boiler, and the need to cool the syngas somewhat from the gasifier

exit temperature before injecting the syngas through the boiler waterwall. The modified configuration was reviewed with DeRidder mill management and Boise corporate personnel in early May. The new configuration was also reviewed at the DOE/AF&PA Agenda 2020 annual project review meeting in Washington DC on May 15th and 16th and in a follow-up project review meeting between DOE and GTI on June 12th in Morgantown, WV.

Preliminary boiler modification study results were reviewed and a list of commercially available candidate tube materials for the high-pressure, high-temperature air heater was selected. Activities were begun in preparation for to the design, installation and evaluation of materials testing experiments to be conducted with samples of the selected materials exposed to actual furnace conditions in PB No. 2. Six different gas turbine configurations were proposed for the Power Island Design Study and two configurations have been selected for further study. Heat and material balance calculations were started for the Gasification Island Design Study.

Additional activities during the reporting period included:

- DOE concurrence was received for the Budget Period 1 Project Evaluation Plan
- A subcontract was placed with Carbona Corporation for the Gasification Island Design Study.
- Service Orders placed with Babcock Borsig Power (BBP) and Solar Turbines, Inc. were replaced as subcontracts.
- Agreement was reached with Nexant on scope and costs for their activities in the Power Systems' Integration Study and Capital and Operating Cost Study.

Activities Next Quarter:

- Define scope and costs for EERC support of the HPHT air heater design
- Execute subcontracts for the System Integration Study, Capital and Operating Cost Study and additional air heater design support.
- Execute Field Test Agreement with Boise DeRidder
- Conduct project review meetings on 7/23-24 at DeRidder
- Fabricate and install air heater tube test system in PB No. 2
- Continue Boiler Modification, Gasification Island, Power Island and Integration Design Studies
- Attend Tappi Pulping and Engineering Conference, AF&PA Black Liquor and Biomass Gasification Program review meeting and follow-on DOE meeting in San Diego, CA September 9-12.

Project Costs and Schedule: The project budget and milestone information is presented in Appendix A.

EXPERIMENTAL

Project Tasks

Phase 1 Predesign Evaluations

In Phase 1 the major technical design and economic factors determining project viability will be evaluated for up to three potential host sites to allow a final host site selection and authorization to proceed to demonstration by Boise Cascade and DOE. These objectives shall be accomplished through the following tasks:

Task 0.0. NEPA Review

GTI and Boise will provide information deemed necessary for DOE to prepare a NEPA review of the project. This information will describe and quantify all anticipated environmental impacts of the project. The NEPA review and approval process will be completed prior to initiation of detailed design studies, or any actions that could prejudice the decision of the NEPA analysis.

Task 1.1. Demonstration Site Evaluations

GTI and Boise will evaluate up to three candidate demonstration host sites at Boise Cascade mills leading to a final host site selection for the demonstration project. The preferred fuels and process configurations will be determined based on site-specific needs, economics and the impact on the cost of steam and electricity produced. Existing plant layouts will be evaluated with respect to design and layout requirements for the gasifier, fuel feeding systems, air heater and turbine system will be evaluated, as well as control integration and modification requirements for the stoker boilers. Permitting requirements will be determined including federal, state and local construction and operating permits required for the demonstration.

Task 1.2. Gasification Island Design Study

Based on the feedstocks identified in Task 1.1, process modeling will be performed using biomass gasification databases to develop gasifier heat and material balances, perform gasifier sizing calculations, predict product fuel gas compositions, and define process input and output flow ranges for candidate feedstocks identified and possible mixtures thereof. Additional design evaluations will include: (a) Fuel preparation, handling and low pressure feeding equipment evaluation; (b) Stoker bottom ash and fly ash evaluation as gasifier fluid bed media, (c) Stoker bottom ash and fly ash handling modifications for recovery and transport to the gasifier; (d) Gasifier bottom ash removal/disposal equipment requirements; and (e) Layout requirements for the gasifier, fuel feeding systems, and syngas ducts.

Task 1.3. Indirect Air Heater System Design Study

The efficacy of utilizing this novel air superheater in the stoker boiler shall be evaluated. Air superheater materials of construction, installation techniques and heat transfer will be evaluated to determine the best superheater design suited for application under biomass-fired stoker conditions. Selection of candidate structural materials will be evaluated, to include test coupon studies in the superheater section of DeRidder's boiler No. 2. The results of these evaluations shall be used to design one or more air heater test sections for pilot performance evaluations in the Boise Cascade boiler in Phase 2.

Task 1.4. Stoker Boiler Modification Study

GTI, Boise and BBP will evaluate the selected boiler with respect to modifications required for the syngas reburn and air superheater retrofits. Evaluations shall include physical layout and condition of the boiler and supporting equipment, as well as operating load ranges, requirement to burn non-condensable gases or pulp mill sludge from the pulping process, availability of alternate steam generating capacity such as natural gas- or oil-fired boilers, combustion stability and need for combustion enhancement, grate type, condition and performance, boiler control hardware, software and data acquisition capabilities, and any other factors that would influence the suitability of the boiler for a successful demonstration.

Task 1.5. Power Island Design Study

Gas turbine design options will be evaluated based on the energy conditions and needs at the DeRidder site. Preliminary specifications will be developed for any modifications required to the turbine generator set, including the combustor, turbine, air compressor, and generator to operate reliably and efficiently with high pressure heated air as the working fluid. Turbine and generator control options will be evaluated with respect to expected load ranges, duty cycles, existing power conditions, and the potential for further integration with existing steam turbines at the site.

Task 1.6. Power Systems Integration Study

GTI, Boise and Nexant will use information from the various design evaluations above as the basis for a power systems integration study which will consider integration of the gasifier, reburners, stoker boiler, high temperature air heater, and gas turbine system controls from the standpoint of operational flexibility, reliability and safety. Operational and control system design requirements will be developed, including safety interlocks and other equipment or operational provisions for boiler, gasifier, and power island trips and combinations thereof. In addition to integration of the individual power system components with each other, the team will evaluate integration of the combined system into the balance of the existing powerhouse. A stepwise implementation strategy will be developed that will reduce technical risk, minimize outage requirements for equipment retrofits, allow early realization of incremental economic and operating benefits for the host site, and accelerate operator understanding and acceptance of the new technologies.

Task 1.7. Capital and Operating Cost Study

The capital costs at the total plant cost level shall be determined by the team and include equipment, materials, labor, indirect construction costs, engineering, and contingencies. Operation and maintenance cost values will be determined. The capital and operating cost results will be combined with plant performance in the comprehensive evaluation of the plant's Cost of Electricity.

Task 1.8. Phase 1 Project Management

GTI will coordinate the work required to accomplish Phase 1. GTI will provide for all project deliverables, including quarterly Financial Status Reports, quarterly Technical Progress Reports, a list of ES&H approvals and a topical report on the complete findings of the Phase 1 Predesign Evaluation. Additionally, GTI will confirm through written endorsements that the demonstration host site and three other like Forest Products Industry companies consider the Boise/GTI demonstration project essential to their management decisions regarding retrofit or replacement of existing boilers and achieving emission levels imposed under EPA promulgated MACT regulations. A summary of these site visits will be included in the Phase 1 Predesign Evaluation report along with the resulting endorsement letters, which will then be presented to the AF&PA's Energy Performance Task Group. Endorsement of the project by the AF&PA Energy Performance Task Group will be necessary to proceed to Phase 2.

GTI and Boise will present the Phase 1 Predesign Evaluation report including all necessary Forest Product Industry endorsements to DOE at the conclusion of Phase 1. A cooperative determination for continuation into Phase 2 shall then be made jointly by DOE, GTI and Boise within 45 days of submission of the Phase 1 Evaluation review.

Phase 2 Demonstration Plant Design Development

Contingent on a decision to proceed based on the results of the Phase 1 Predesign Evaluations, pilot-scale verification of the air heater design, and a detailed engineering design and cost estimate for the retrofit will be completed in Phase 2. The project team will prepare the Phase 2 Design and Cost Estimate for presentation to DOE upon completion. A cooperative determination for continuation into Phase 3 shall be made jointly by DOE, GTI and Boise within 45 days of submission of the Evaluation Review.

Phase 3 Procurement and Construction

Equipment purchase, subcontract procurement, retrofit construction and permitting will be completed in Phase 3.

Phase 4 Demonstration Plant Operations

Demonstration plant startup, verification of mechanical completion, operability testing, performance tests in integrated power generation mode, and commercial demonstration operations shall be completed during Phase 4.

RESULTS AND DISCUSSION

Task 0.0. NEPA Review

There were no activities in this task during the quarter.

Task 1.1. Demonstration Site Evaluations

The objective of this task was completed with the agreement by the DeRidder mill to be the host site for the advanced gasification-based power system demonstration. Since this was accomplished without the additional site evaluations originally proposed, DOE has agreed that GTI will perform preliminary site evaluations to obtain project endorsements from three FPI companies other than Boise. This will be performed under Task 1.8 within the budgeted costs for Phase 1.

Task 1.2. Gasification Island Design Study

The revised power system configuration is shown in Figure 1. The Gasification Island Design Study scope includes development of the gasifier system design basis and conceptual design of the feed dryer, fuel feeding system, gasifier, ash removal system, tar cracker and syngas cooling to 600 F. Heat and material balances, PFDs and P&IDs will be developed for the gasification section, along with equipment specifications and sizing, utilities requirements and preliminary layout drawings. Equipment, erection and operating cost estimates will then be prepared for incorporation into the overall power system cost evaluation.

The Gasification Island design basis was developed during the quarter based on vitiated air from the gas turbine (GT-1) exhaust as the oxidant stream for the gasifier. Preliminary heat and material balance calculations were performed for the gasifier to determine the syngas quantity and composition produced, including combustion of a portion of the syngas ahead of the air heater to achieve air outlet temperatures of 1400°F. Prior to entering the turbine, the air temperature is boosted further to meet the turbine inlet temperature requirement of 2200°F using natural gas in the turbine's combustor. Two cases – combustion air at 850°F from the turbine compressor (air heater in parallel with the combustor) and combustion air at 1400°F from the air heater (air heater in series with the combustor as in Figure 1) will be calculated.

Task 1.3. Indirect Air Heater System Design Study

The main activity in this task during the quarter was the selection of candidate tube materials for the HPHT air heater and planning for in-furnace testing of these tubes. The stoker boiler's HPHT air heater will be sized to supply air to only one of the two Solar Titan 130 gas turbines due to space and heat limitations in Power Boiler No. 2. Heat required to supply high temperature air for the second Titan 130 will be supplied by heat exchange with hot syngas prior to the stoker. The Titans will produce 14 MW of electric power each. The separate air heaters will have their tubes exposed to different gas environments – oxidizing in the stoker and

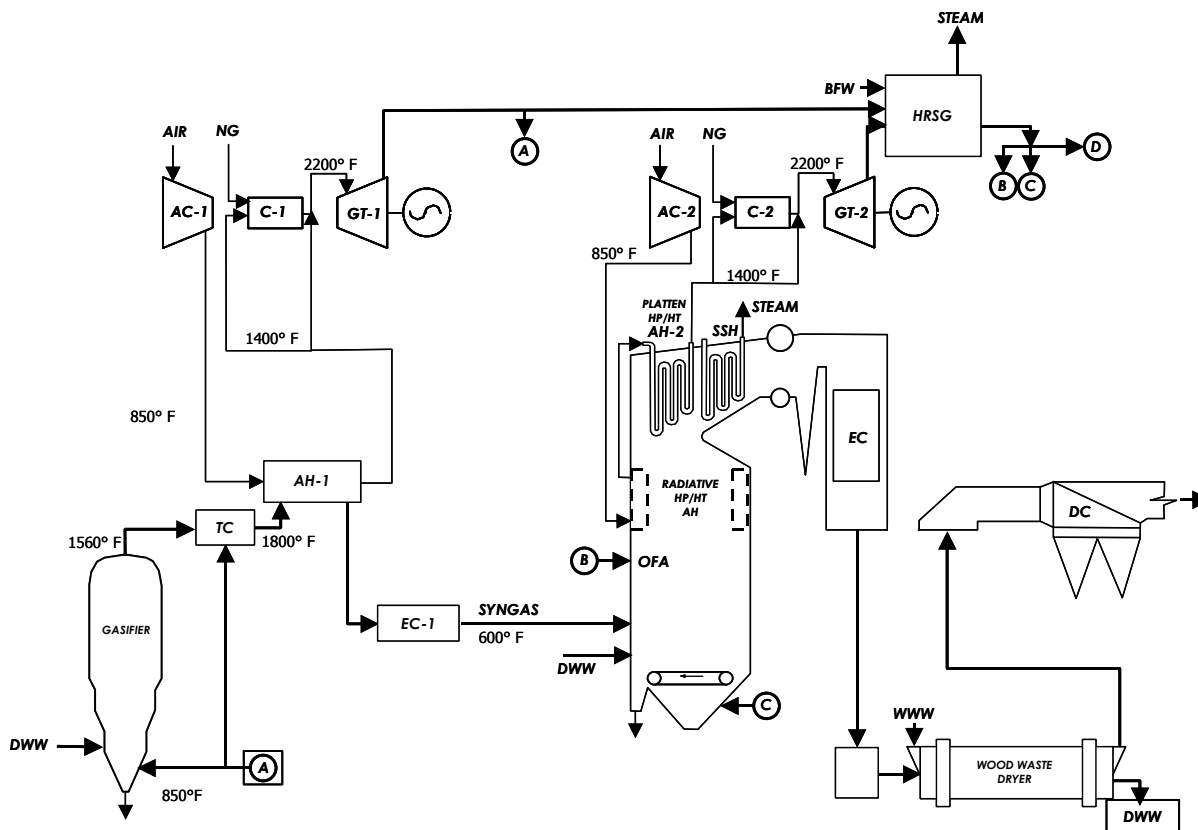


Figure 1. Revised Power System Configuration

reducing after the gasifier. Sample tubes will therefore be tested in two different zones in the boiler: near the grate where fuel rich conditions simulate the reducing atmosphere after the gasifier, and at the top of the furnace in front of the existing superheater banks.

Design of the tube testing experiment was begun, and preliminary locations were selected in the boiler using existing access ports. It is expected that at least four different materials will be tested in both locations, at metal temperatures ranging from 1200°F to 1600°F and exposure times up to 6 weeks.

Task 1.4. Stoker Boiler Modification Study

The initial evaluation of PB No. 2 with respect to the HTHP air heater resulted in splitting the air heating duty between two heaters as discussed above. Efforts were then focused on evaluating the revised configuration, including the effects of drying the stoker's bark fuel to 20 % from about 50% and reducing the boiler's steam production by about 50,000 lb/h. (Note that a Heat

Recovery Steam Generator (HRSG) has been added to the system to generate about 80,000 lb/h of steam, increasing the overall steam output from the system by about 30,000 lb/h). Both of these changes significantly increase the high temperature heat available for heating air in the boiler, providing air outlet temperatures as high as 1400-1600°F. Several configurations for the HPHT air heater are being evaluated to accommodate the required surface area in the boiler. Final furnace configuration and temperature calculations will be done when the syngas composition and conditions are fully characterized from Task 1.2.

Task 1.5. Power Island Design Study

Six potential configurations were defined for the HPHT air heater and turbine systems. Two configurations shown in Figure 2 below were selected for further study. In the parallel configuration, air routed directly from the turbine is used as combustion air in the turbine combustor, requiring more natural gas to achieve the required turbine inlet temperature. This approach is the same as is currently used for the combustor, and is expected to require the smallest change from current combustor design. The parallel option uses more natural gas for

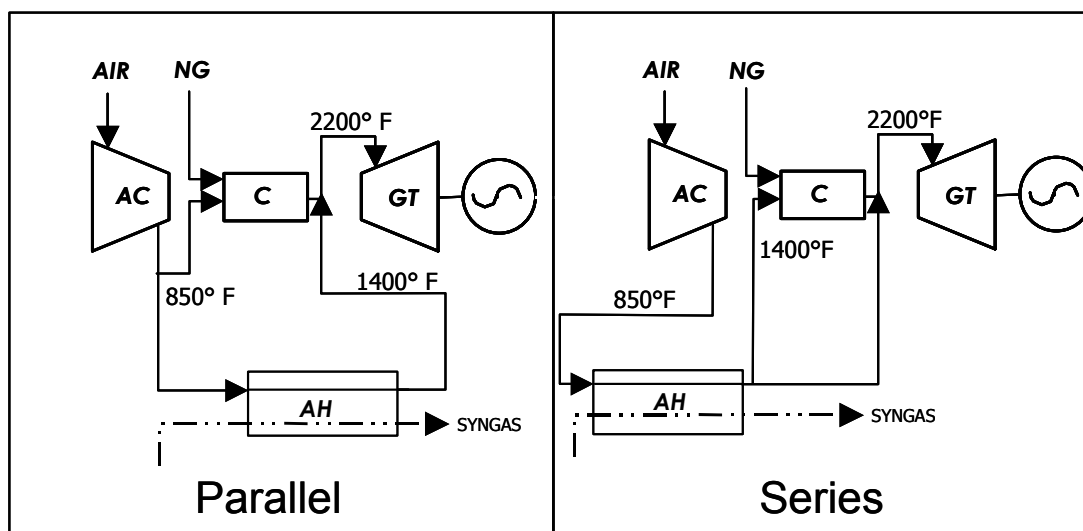


Figure 2. Power Island configurations selected for further evaluation.

power production than the series configuration, which uses more energy from biomass by using air from the HPHT air heater as the turbine combustor combustion air. The high combustion air temperature may require modification to the combustor to prevent flashback, particularly if air temperatures reach the 1600°-1800°F range.

Both of the above cycles will be evaluated for air temperatures of 1400°-2000°F over a range of compressor inlet temperatures, HTHP air heater pressure drops, turbine inlet temperatures and outlet pressures.

Task 1.6. Power Systems Integration Study

The DeRidder mill steam and power objectives were defined to include 28 MW of additional self-generated power while maintaining or increasing steam production at or above current levels. Information on the mill's current steam production and distribution system was received for evaluation to determine the most energy- and cost-effective ways to utilize the two-air heater/two-turbine system, including the optimum steam conditions for steam generated in the

HRSG. Currently, process steam is primarily supplied from the existing steam turbine exhaust, and steam and power production are therefore closely coupled.

In addition to satisfying the various design constraints at the DeRidder site, the two-air heater system facilitates stepwise implementation of the advanced power system by allowing the gasifier, syngas cooler/air heater and one of the two 14MW turbines to be installed before major modifications are required to the stoker for the HIPPS air heater installation. The equipment, piping and controls for this first portion of the system can be installed while the boiler is maintained in normal operation, with only a 5-7 day outage required for final tie-ins. The benefits to the mill from this first step will be significant, including an additional 14 MW of self-generated power and NO_x reduction from the stoker boiler of 40-60% from syngas reburning. Shakedown and debugging of the gasification, air heating and turbine systems can be accomplished with minimum impact on boiler operations and availability.

To continue the Integration Study, information will be obtained on the mill's Balance of Plant requirements, including the electrical interface, availability of boiler feed water, cooling water, instrument air, fire protection, MCC center and process control system capacities.

Task 1.7. Capital and Operating Cost Study

No activities were conducted in this area during this period. Information on the costs of bark, natural gas and purchased electricity will be provided by the mill, as well as seasonal variation in the mill's steam and electricity demand. This, together with capital and operating cost inputs from the various design studies, will be consolidated for the overall system economic evaluation.

Task 1.8. Phase 1 Project Management

The overall project status, including the revised power system configuration, was presented at the Agenda 2020 Energy Performance Task Group Project Review Meeting May 15-16 in Washington D.C. A second project review meeting was attended by GTI at NETL on June 12 in Morgantown, WV.

Additional activities during the reporting period included:

- DOE concurrence was received for the Budget Period 1 Project Evaluation Plan
- A subcontract was placed with Carbona Corporation for the Gasification Island Design Study.
- Service Orders placed with Babcock Borsig Power (BBP) and Solar Turbines, Inc. were replaced as subcontracts.
- Agreement was reached with Nexant on scope and costs for their activities in the Power Systems' Integration Study and Capital and Operating Cost Study.

CONCLUSION

The overall power system configuration has been revised to accommodate space and heat limitations in the existing stoker boiler and site-specific steam and electricity requirements. The revisions add somewhat to system complexity but improve the technical feasibility of the system for the DeRidder mill. The impact of these revisions on operability, reliability and overall power system cost effectiveness will be favorable and will be fully defined during the current Phase 1 evaluation. Further refinement of these approaches may be explored during the study to minimize technology risk and insure a cost effective system design.

Work Planned for Next Quarter:

- Define scope and costs for EERC support of the HPHT air heater design
- Execute subcontracts for the System Integration Study, Capital and Operating Cost Study and additional air heater design support.
- Execute Field Test Agreement with Boise DeRidder
- Conduct project review meetings on 7/23-24 at DeRidder
- Fabricate and install air heater tube test system in PB No. 2
- Continue Boiler Modification, Gasification Island, Power Island and Integration Design Studies
- Attend Tappi Pulping and Engineering Conference, AF&PA Black Liquor and Biomass Gasification Program review meeting and follow-on DOE meeting in San Diego, CA September 9-12.

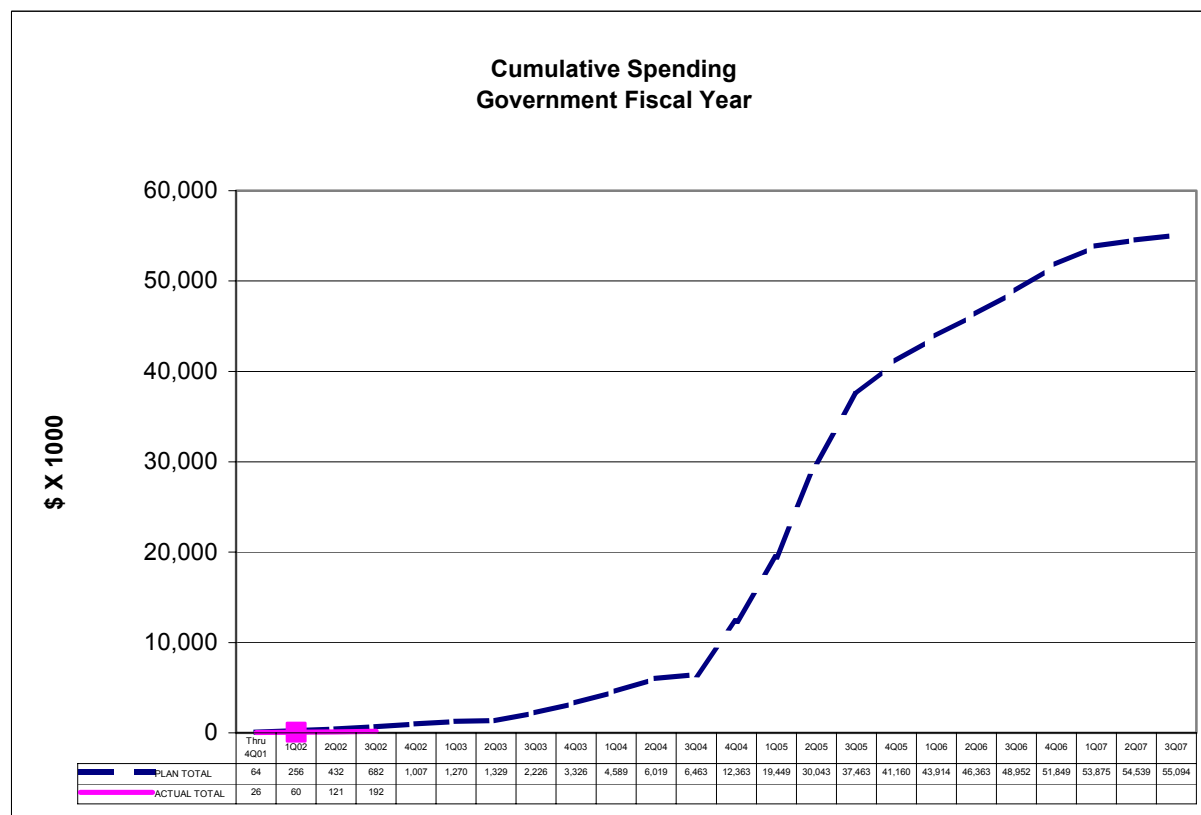
Appendix A**Project Costs**

| Project Budget Period | | Period | | | Cumulative | | |
|-----------------------|---------|-----------|-----------|-----------|------------|--------|---------|
| From | To | DOE* | Share* | Total | DOE | Share | Total |
| 4/1/02 | 6/30/02 | \$ 43,109 | \$ 27,824 | \$ 70,933 | 111,886 | 79,871 | 191,757 |
| Previous Total | | \$ 30,155 | \$ 30,829 | \$ 60,984 | 58.3% | 41.7% | 100.0% |

Budget Data

| | | | | | | | | | | | |
|---------------------------|-----------|--|------------|------------|------------|------------|------------|---------------|-----------|-----------|----------|
| GTI, Boise Cascade | | Advanced Gasification-Based Fuel Conversion and Electric Energy Production System (1691) | | | | | | | | | |
| FC26-01NT41108 | | Rabovitser | | | | | | | | | |
| Project Budget Periods | | Approved | | | | | | DOE Obligated | | | |
| | | Incremental | | | Cumulative | | | Mod | Increm | Cumul | Date |
| From | To | DOE | Share | Total | DOE | Share | Total | A000 | 1,028,010 | 1,028,010 | 8/8/2001 |
| 7/15/2001 | 3/31/2003 | 1,028,010 | 300,500 | 1,328,510 | 1,028,010 | 300,500 | 1,328,510 | | | | |
| 4/1/2003 | 6/30/2007 | 25,965,065 | 27,800,000 | 53,765,065 | 26,993,075 | 28,100,500 | 55,093,575 | | | | |
| Total | | 26,993,075 | 28,100,500 | 55,093,575 | 49.0% | 51.0% | 100.0% | | | | |

Note: Only the first budget period has been approved. The second budget period is estimated.

Cost Curve

Schedule and Milestones

